Visualization and Modeling Working Group

(formerly titled: Predicting Impacts on Utility Infrastructures: Lessons Learned from the 2005 Hurricane Season)

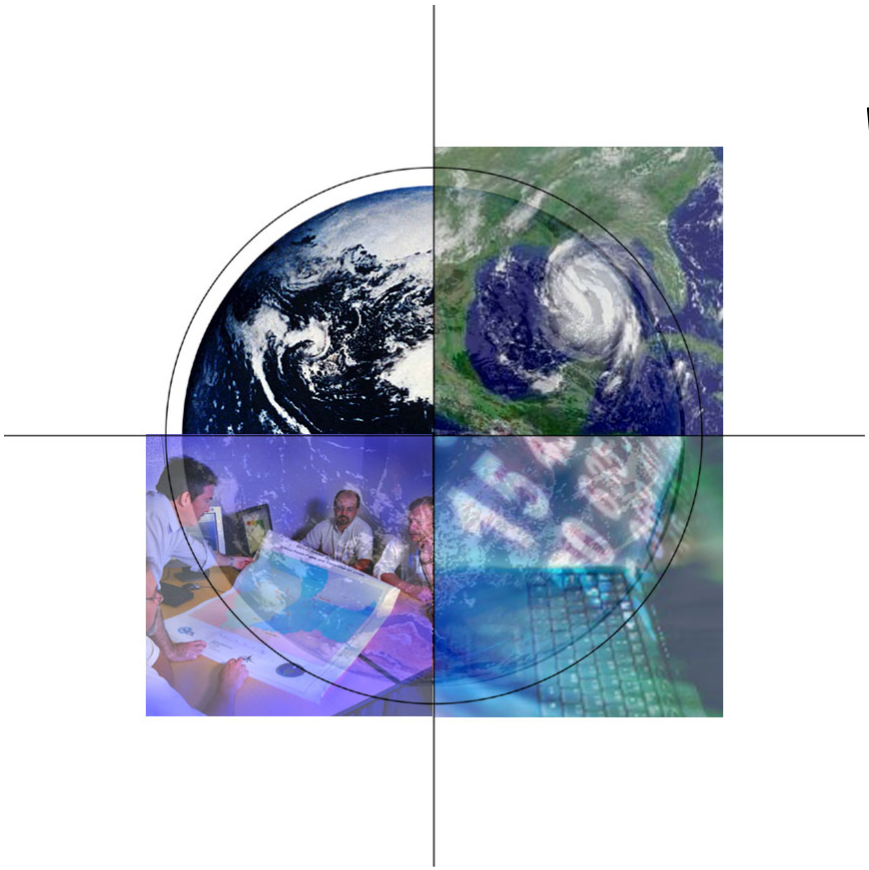
Steven Fernandez, *Group Leader, Energy & Infrastructure Analysis Group,* LOS ALAMOS NATIONAL LABS/NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Keith Dodrill, *Energy Infrastructure & Security Analysis*, NATIONAL ENERGY TECHNOLOGY LABS

During the 2005 Hurricane season, many consequence predictions were available from 36 to 96 hours before landfalls, via the Department of Energy's Visualization and Modeling Working Group (VMWG). Real-time data can be tapped by local officials and utilities, and can also be accessed for post-event regulatory audits. An overview of VMWG's models, results and uses will be presented.

Emergency Preparedness and Service Restoration for Utilities Conference, March 28-30, 2007, New Orleans

Office of Electricity Delivery and Energy Reliability



Visualization and Modeling Working Group

Keith Dodrill – VMWG Coordinator
March 29, 2007
Keith.Dodrill@netl.doe.gov
(304-285-4152)

Stephen J Fernandez
(865-576-3565)

NETL

Visualization and Modeling Working Group VMWG DOE-ANL-LANL-NETL-ORNL-PNL-SNL

Los Alamos NATIONAL LABORATORY

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Creation of Working Group

- **August 2003 Blackout – Realization of need for "real time" expert analysis for energy emergencies**
  - Specifically for DOE senior level decision makers
- **OE assessed DOE's visualization, modeling, and data capabilities**
- **Need to share these visualization, modeling, and data efforts across National Laboratories**
- **September 2003 - OE formed Visualization and Modeling Working Group (VMWG)**
- **Comprised of data and infrastructure experts from:**
  - Office of Electricity Delivery and Energy Reliability (OE)
  - DOE National Laboratories
  - Energy Information Administration (EIA)
  - Other Federal Agencies

Mission

- **Identify near-term steps to improve DOE and the Emergency Operations Center capabilities to visualize, model, and simulate the U.S. energy system.**
- **Facilitate cooperation across the relevant DOE offices and laboratories.**
- **Establish a sophisticated energy visualization system that would be available in the event of an energy emergency.**
- **Provide the framework for improving analytical capabilities during energy emergencies.**

Hurricane Katrina Aug 25, 2005

VMWG Roles and Responsibilities

- **Provide senior level DOE staff key asset information**
  - Rapid Response ~ 1 Hour ⟹ Full lab response in less than 8 hours
  - GIS based analysis of key infrastructures
  - Statistical analysis of infrastructures and their interdependencies
- **Build agency partnerships**
  - National Laboratories
  - Regulatory agencies such as FERC
  - Private sector groups such as Financial Services Sector Coordinating Council (FSSCC)
  - DHS, USACE, Dept of Treasury, Dept of Defense, etc.

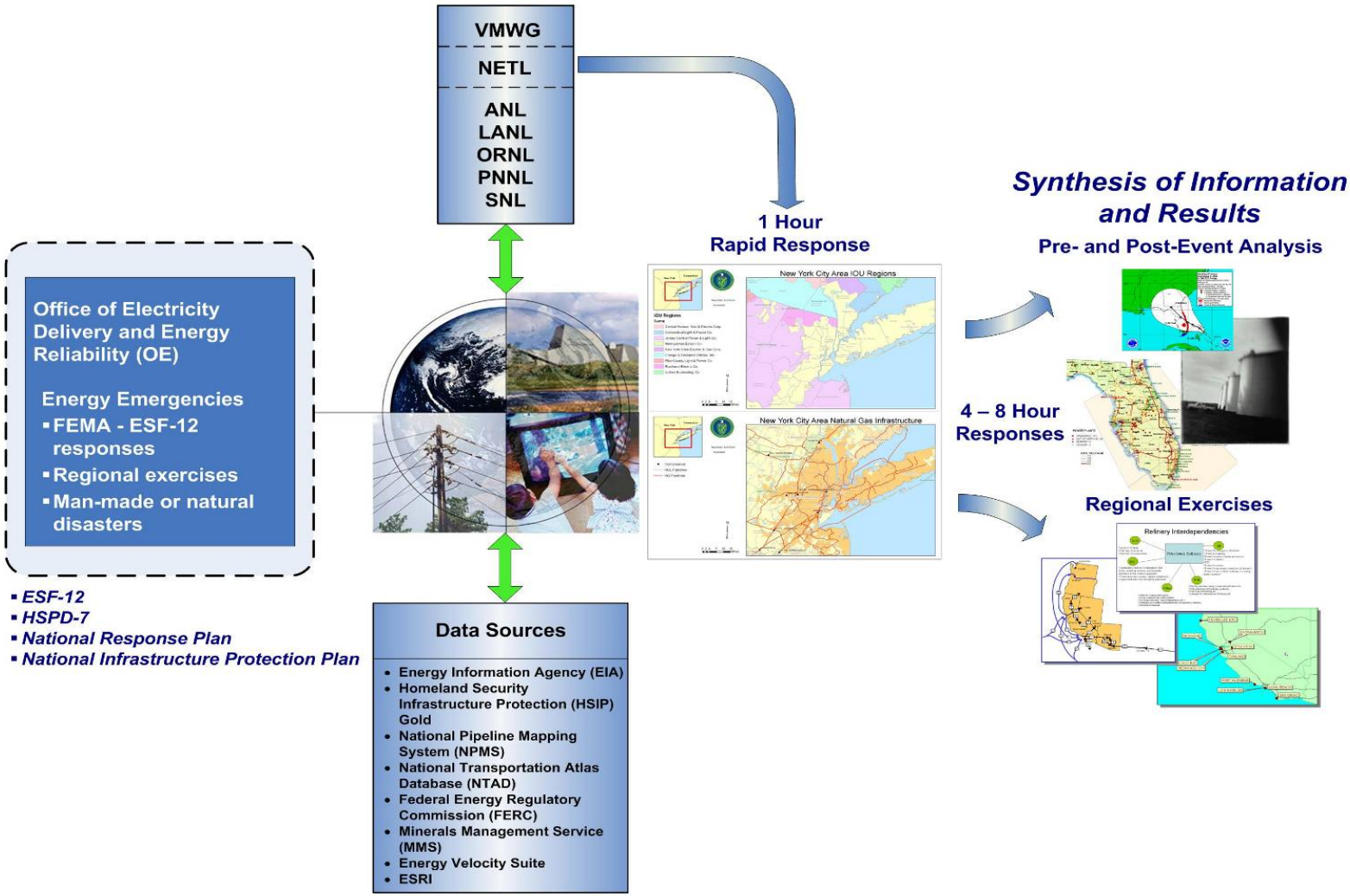
Agency Accessibility to Analysis

- Government
  - DOE National Laboratories
  - DOE/OE/HQ
  - Dept. of Transportation
  - Dept. of Defense
  - Energy Information Administration
  - Dept. of Homeland Security
  - FERC
  - NERC
  - Dept. of Interior
  - Dept. of Treasury
  - U.S. Army Corps of Engineers
  - Dept. of Veterans Affairs
  - U.S. Air Force
- Non Government
  - Florida Power Corp.
  - Florida Power & Light
  - ABS Consulting
  - Canada Natural Resources
  - BITS Financial Roundtable
  - Energetics
  - ICF Consulting
  - State Line Energy
  - Finance ISAC SOC
  - Pershing LLC
  - Goldman Sachs
  - Options Clearing (FSSCC)
  - NiSource
  - American Gas Assoc.
  - Duke Energy
  - Dominion Energy
  - Edward Jones
  - National Petroleum Refiners
  - Valero
  - ExxonMobil
  - American Petroleum Institute

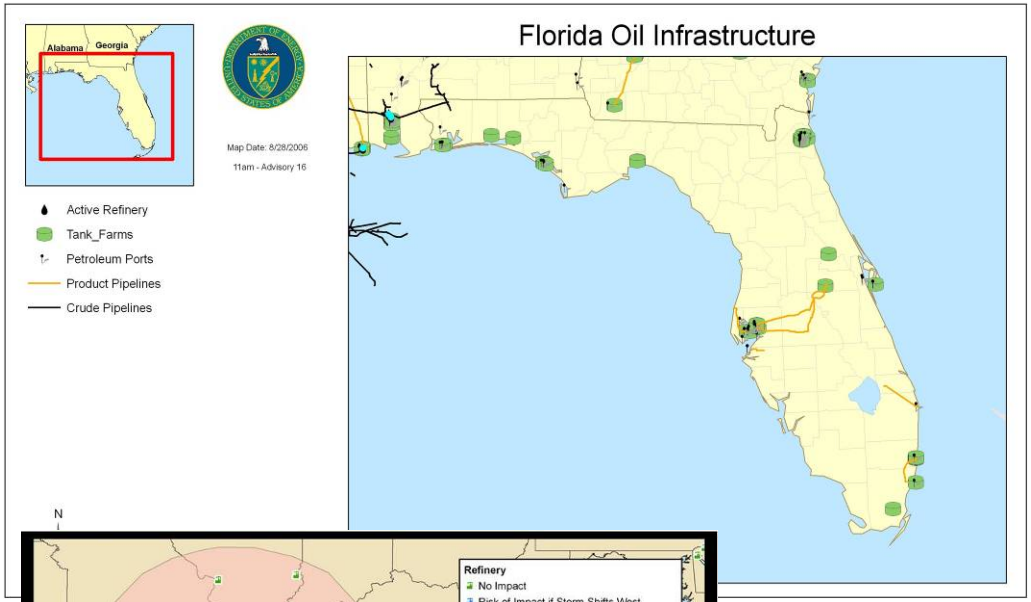
National Laboratories Responsibilities

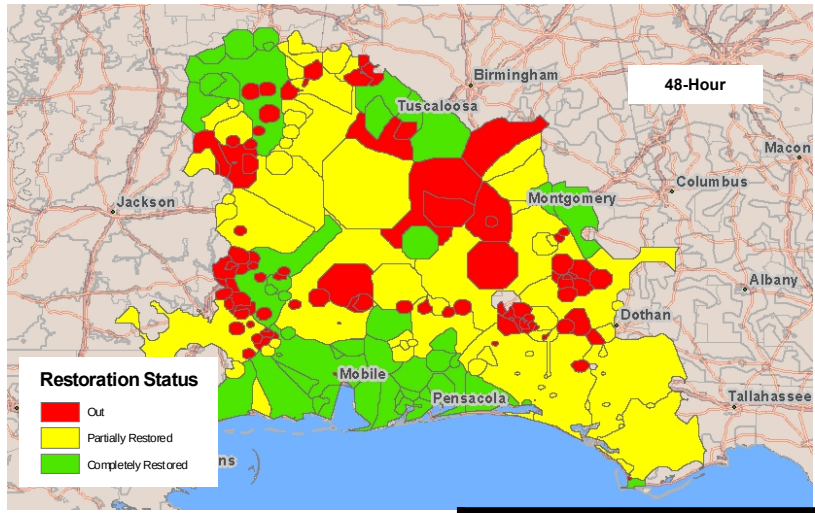
Argonne	**Natural Gas and Oil Infrastructure**
Los Alamos	**Electrical Outage and Restoration**
Oak Ridge	**Population /Transportation/Ports**
Sandia	**Economic Interdependencies**
NETL	**VMWG Coordination of Analysis** **1-Hour Rapid Response**
Pacific Northwest	**Electric Grid and Industry Coordination**

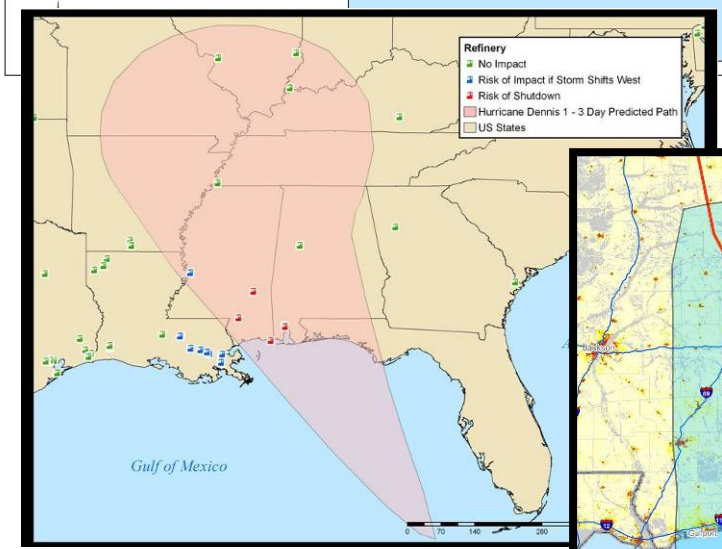
Visualization & Modeling Working Group (VMWG) Response Model

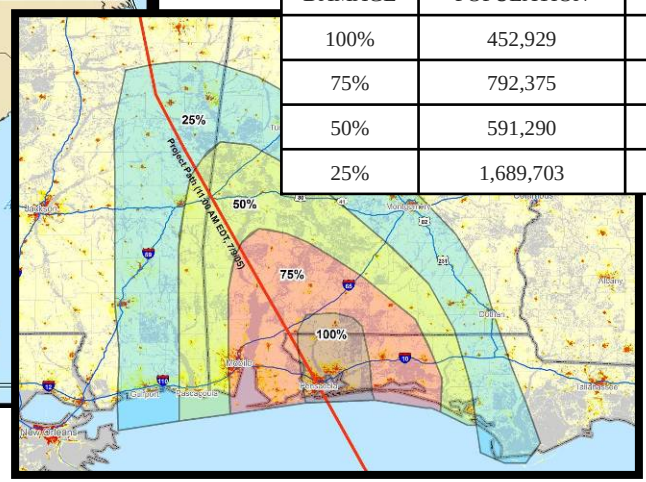


VMWG Product









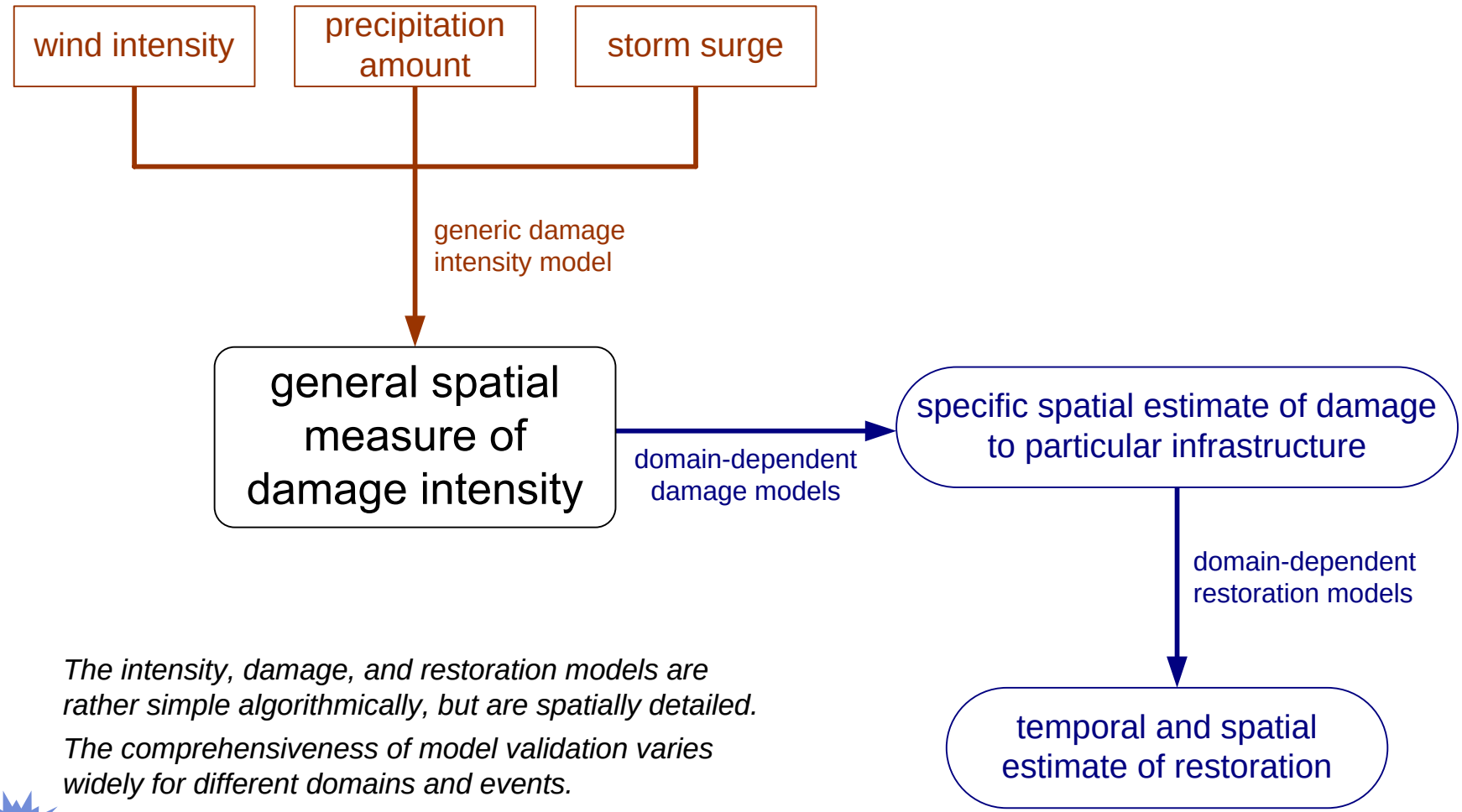
DAMAGE	TOTAL POPULATION	CUMULATIVE
100%	452,929	452,929
75%	792,375	1,245,304
50%	591,290	1,836,594
25%	1,689,703	3,526,297

Major Ports	
PORT	Average Daily Short Tons
Gulfport	6,968
Mobile	70,991
New Orleans	705,239
Panama City	1,826
Pascagoula	57,045
Pensacola	887

NETL

Visualization and Modeling Working Group
VMWG
DOE-ANL-LANL-NETL-ORNL-PNL-SNL

General Methodology



The intensity, damage, and restoration models are rather simple algorithmically, but are spatially detailed.

The comprehensiveness of model validation varies widely for different domains and events.

Analysis Inputs

- **Existing**
  - NHC forecasts for track and intensity
  - METOC wind contours
  - USACE storm surge and flood models
- **Experimental (in process)**
  - Wind and precipitation fields from NWP model outputs
  - *Ad hoc* use of published ensembles
    - Model comparison
  - New flood model
- **Desired**
  - Probabilistic framework
    - Rigorous use of ensembles
    - Historical data
  - 3-7 day landfall and intensity estimates
  - Wind, precipitation, storm surge, and flood reconstruction immediately after landfall
  - Infrastructure damage validation studies
  - Wind spectra from NWP model outputs

Data Processing Challenges

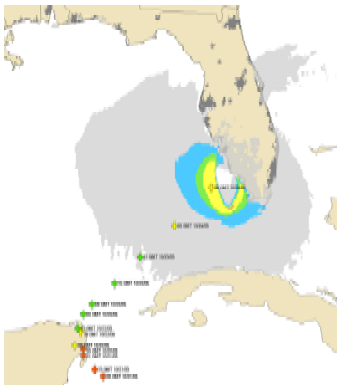
- **Heterogeneous raw data:**
  - Different data services: FTP, HTTP, MSS.
  - Different data formats: text, netCDF, GRIB2.
  - Different metadata: netCDF, GRIB2, file names, e-mail.
  - Different time samples: hourly, six-hourly, irregular.
  - Different field names and definitions.
  - Different domains, grids, and projections.
- **Large data sets:**
  - E.g., WRF hurricane run is ~30GB per 72-hour forecast.
  - WRF is run twice daily, RT-FDDA eight times daily, GFDL four times daily.
- **Goals:**
  - Achieve a uniform visual representation.
  - Maintain full precision of raw data.
  - Navigate and compare forecasts easily and quickly.
  - Synchronize presentation of time series.

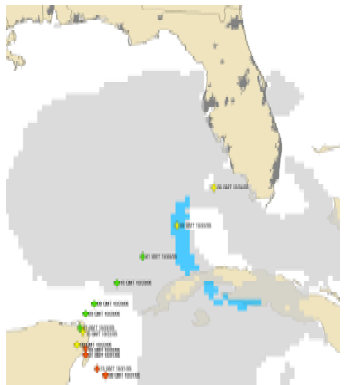
Experimental Products for 2005 Season

		WRF 4km	WRF 12km	RT-FDDA (MM5)	GFDL Hurricane	NAM/ETA	SREF Ensemble	MRF Ensemble
Katrina	Pre-landfall					√		
	Post-landfall	√				√		
Ophelia	Pre-landfall	√	√		√			
Rita	Pre-landfall	√	√	√	√		√	√
Wilma	Pre-landfall	√	√	√	√			

- **NWP experimental damage estimation products for the 2005 Hurricane outputs were used as inputs for season.**
  - These products provide much higher spatial and temporal resolution, and consequently require more effort to validate than lower resolution products.
  - The existence of multiple NWP model forecasts has opened the possibility of using ensemble methods for statistical and probabilistic damage estimate forecasts.

Wilma NWP Model Output Comparison



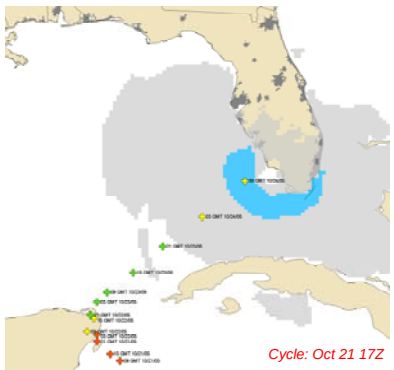


Tropical Depression
Tropical Storm
Category 1 Hurricane
Category 2 Hurricane
Category 3 Hurricane
Category 4 Hurricane
Category 5 Hurricane

Numerical Models

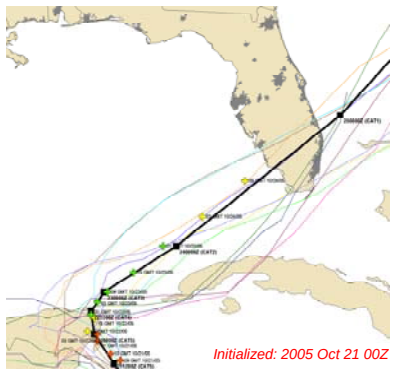
NOAA/HRD Reconstruction

RT-FDDA(MM5) 12km: Valid 2005 Oct 24 14Z
Maximum (U10,V10) wind: 41.7 m/s



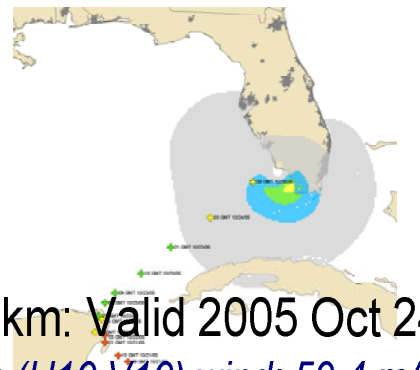
Cycle: Oct 21 17Z

Official Forecast and Other NWP Model Tracks
Forecast for maximum wind just prior to landfall: 48.9 m/s



Initialized: 2005 Oct 21 00Z

Valid 2005 Oct 24 1030Z
Maximum (SFC_U,SFC_V) wind: 51.3 m/s

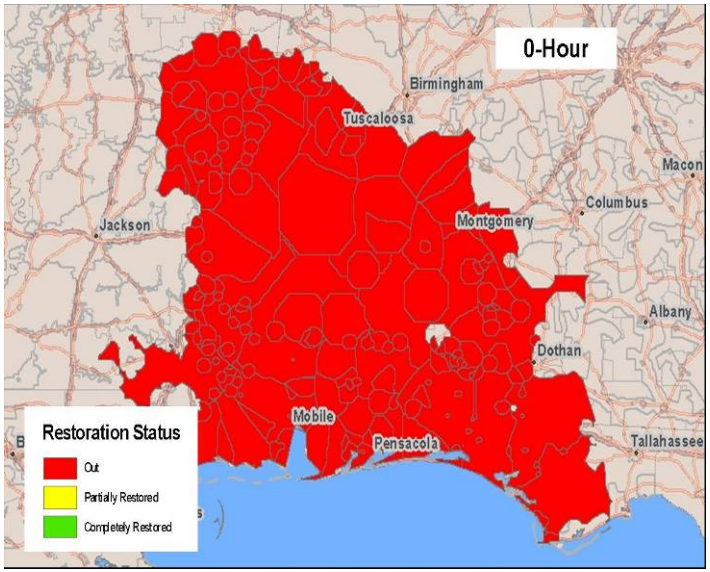


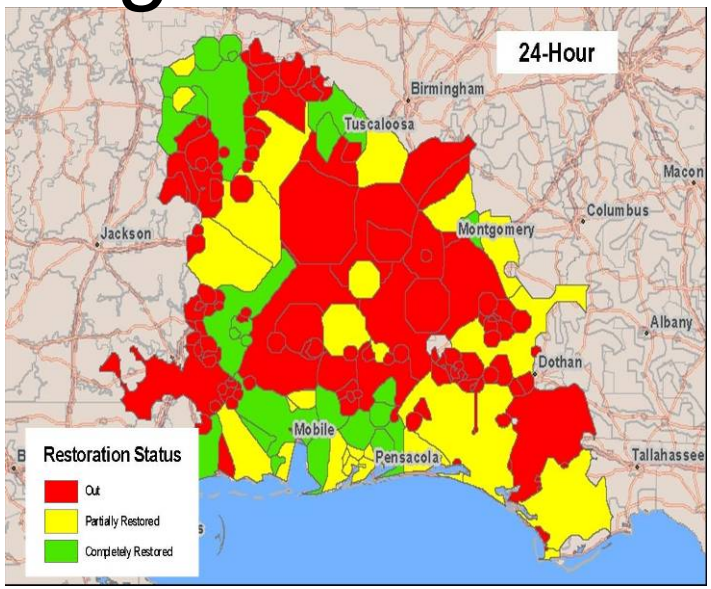
WRF/ARW 4km: Valid 2005 Oct 24 18Z
Maximum (U10,V10) wind: 59.4 m/s

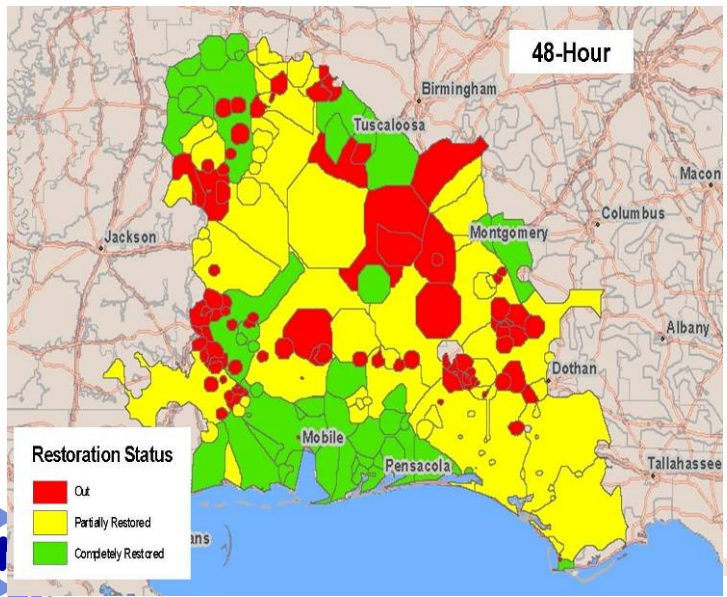
NETL

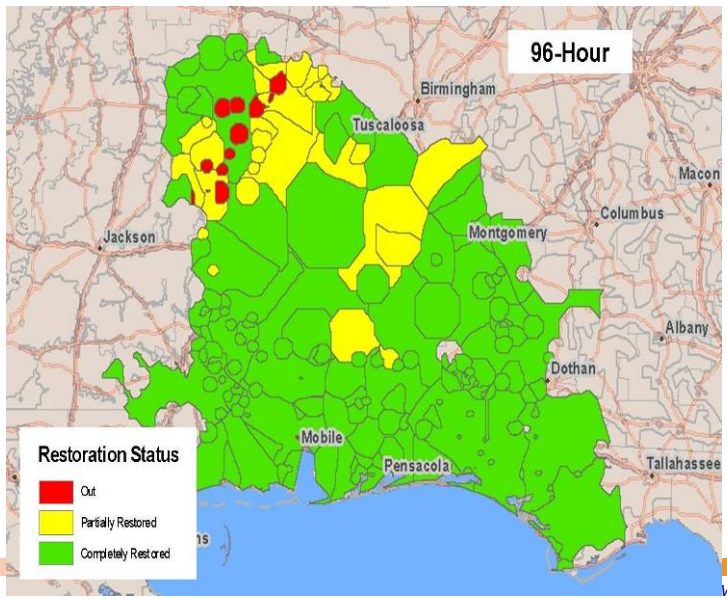
Visualization and Modeling Working Group
VMWG
DOE-ANL-LANL-NETL-ORNL-PNL-SNL

Hurricane Dennis Outage Restoration



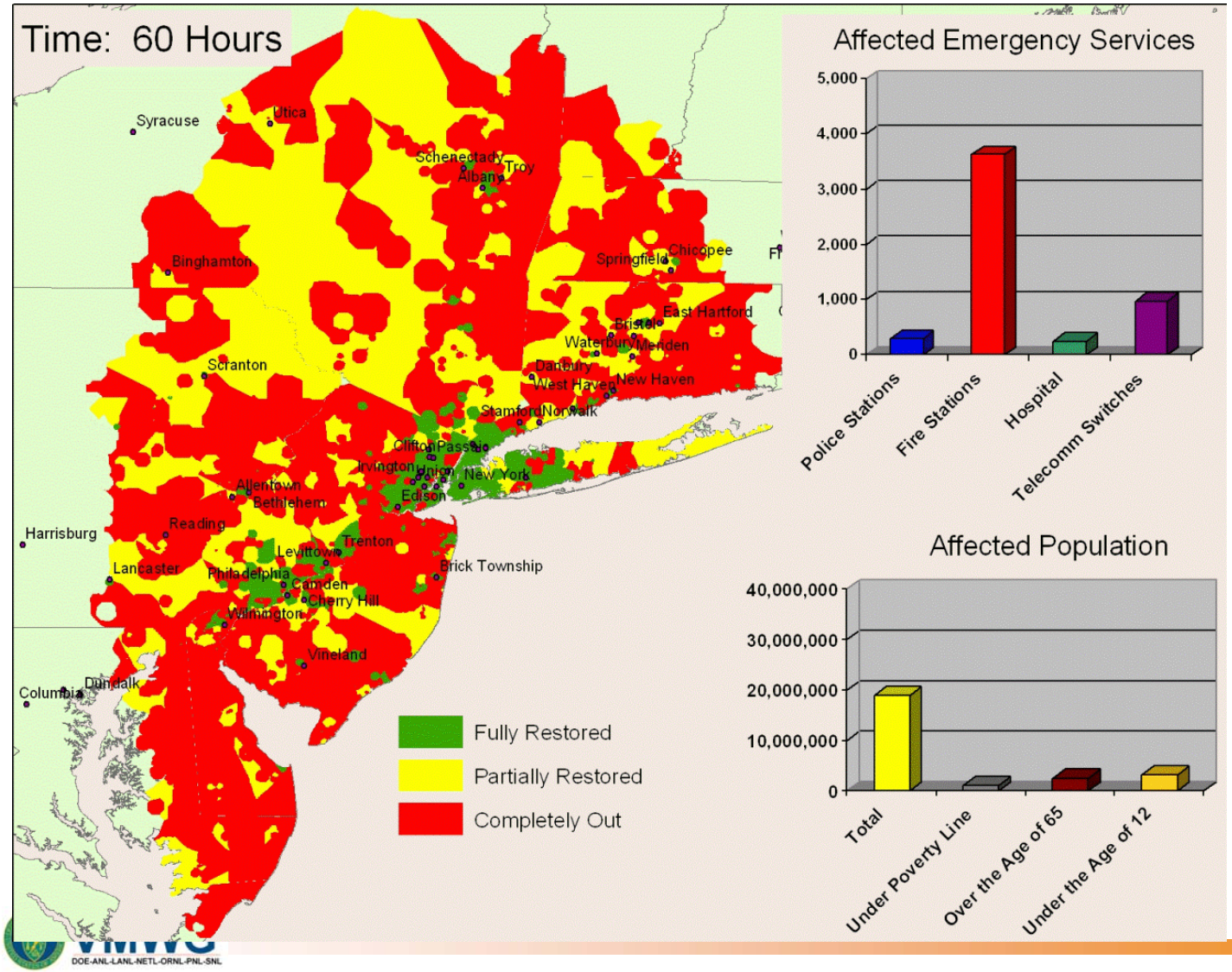




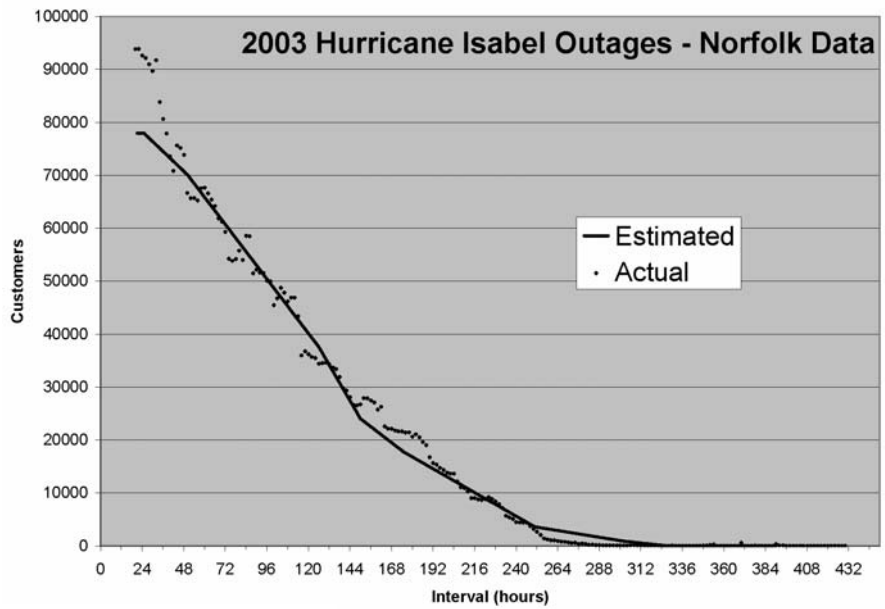


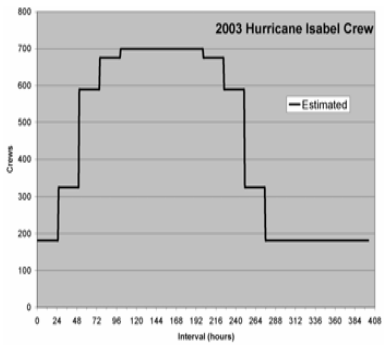
LA-UR-05-9387

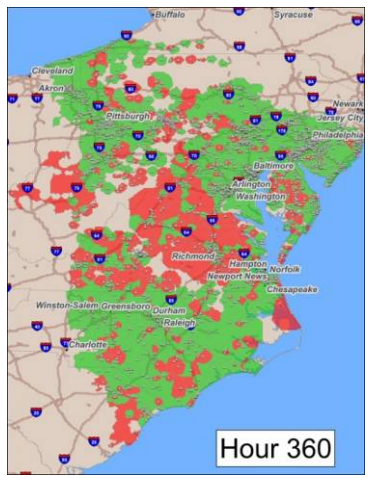
Restoration for Example Cat 3 Hurricane for NYC



Example Validation for Electric Power Restoration



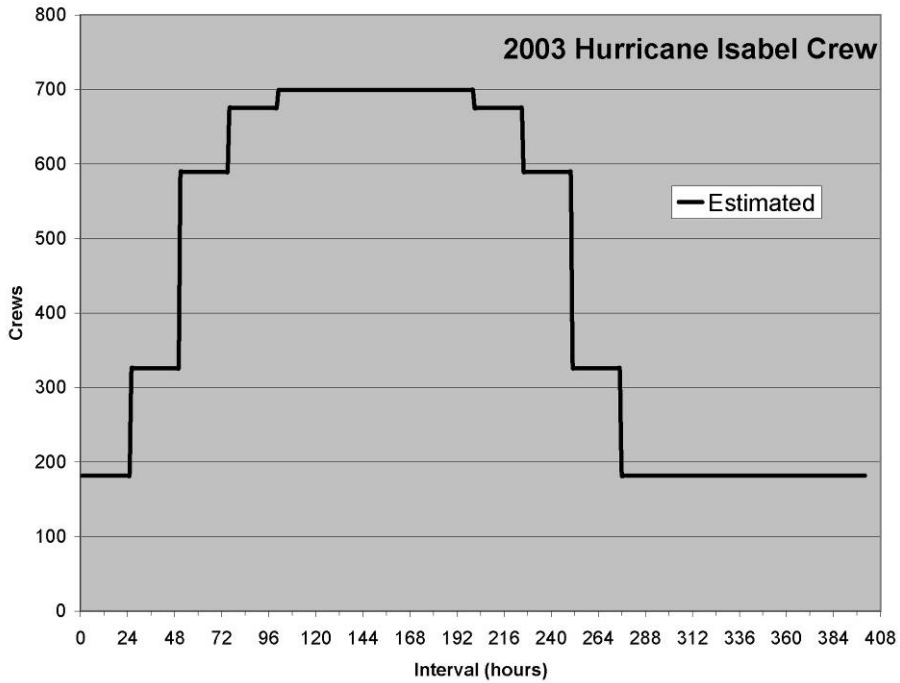


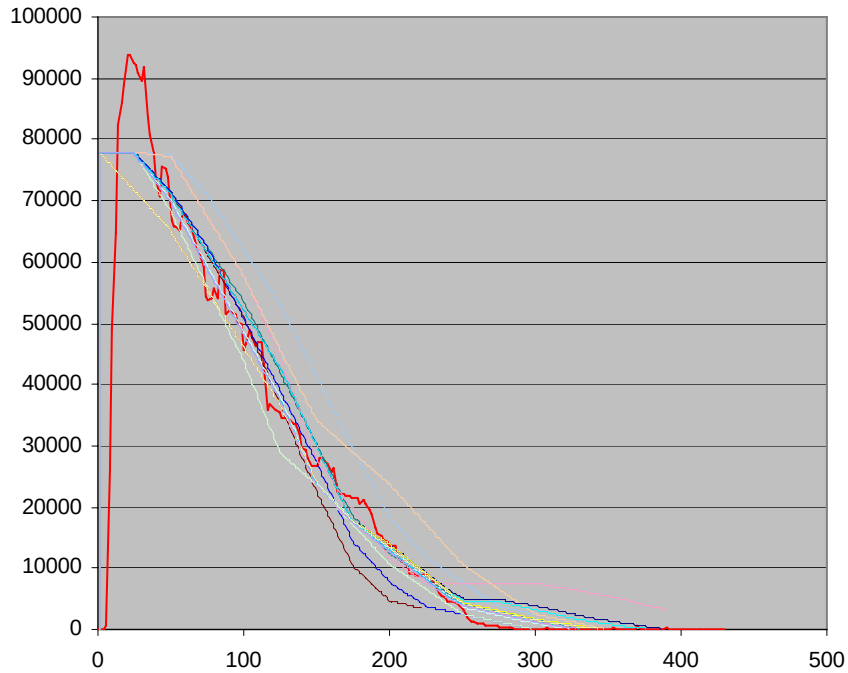


Algorithm Ingredients:

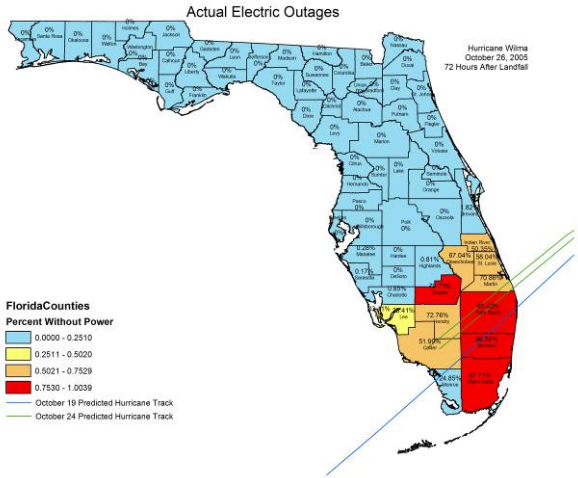
1. "Black start" generators.
2. Generator ramp times.
3. Network connectivity.
4. Crew constraints.
5. Engineering rules of thumb.
6. Historical data.

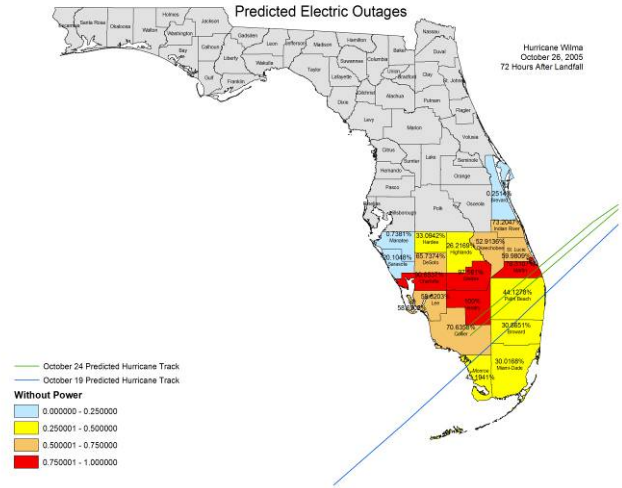
Restoration Crew Validation

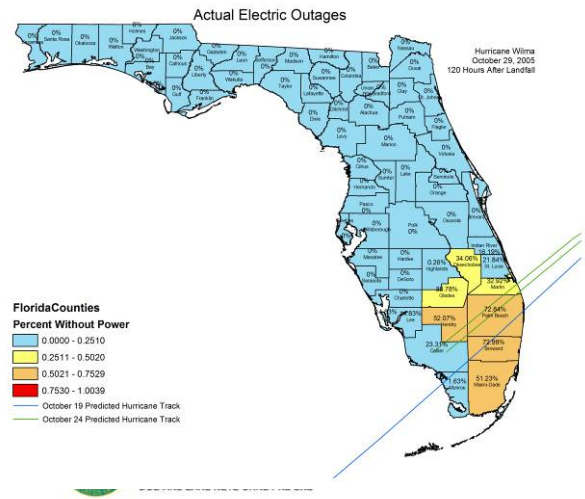


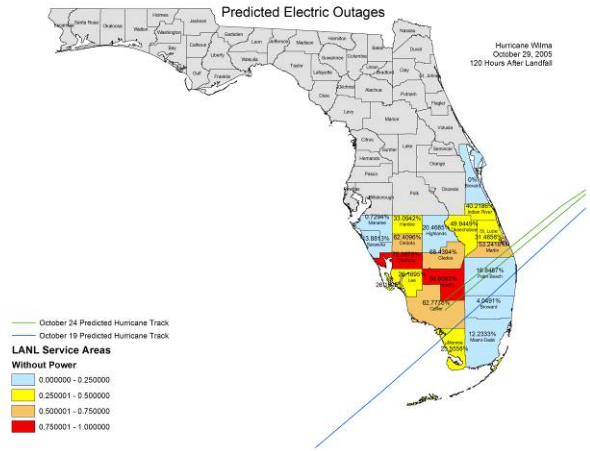


Time History – Actual vs. Predicted

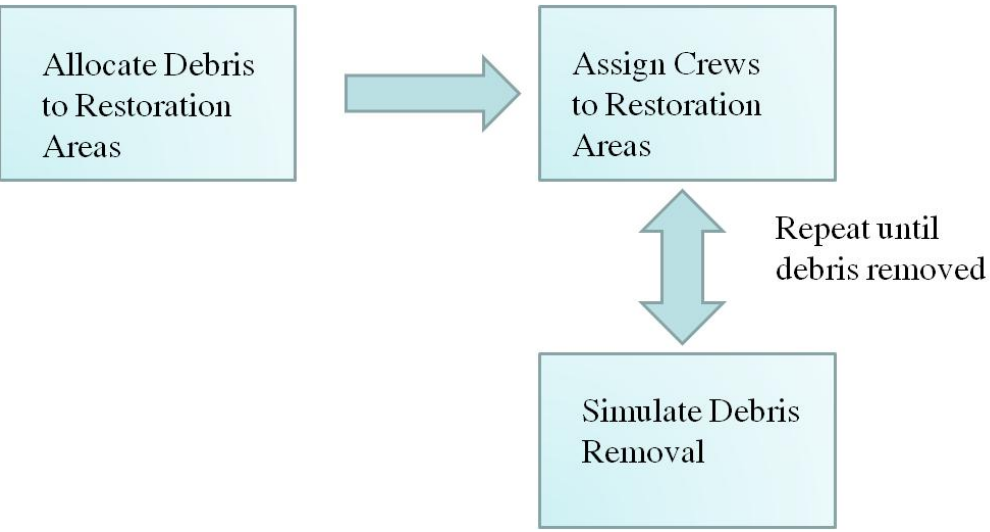








Debris Restoration Simulator Overview



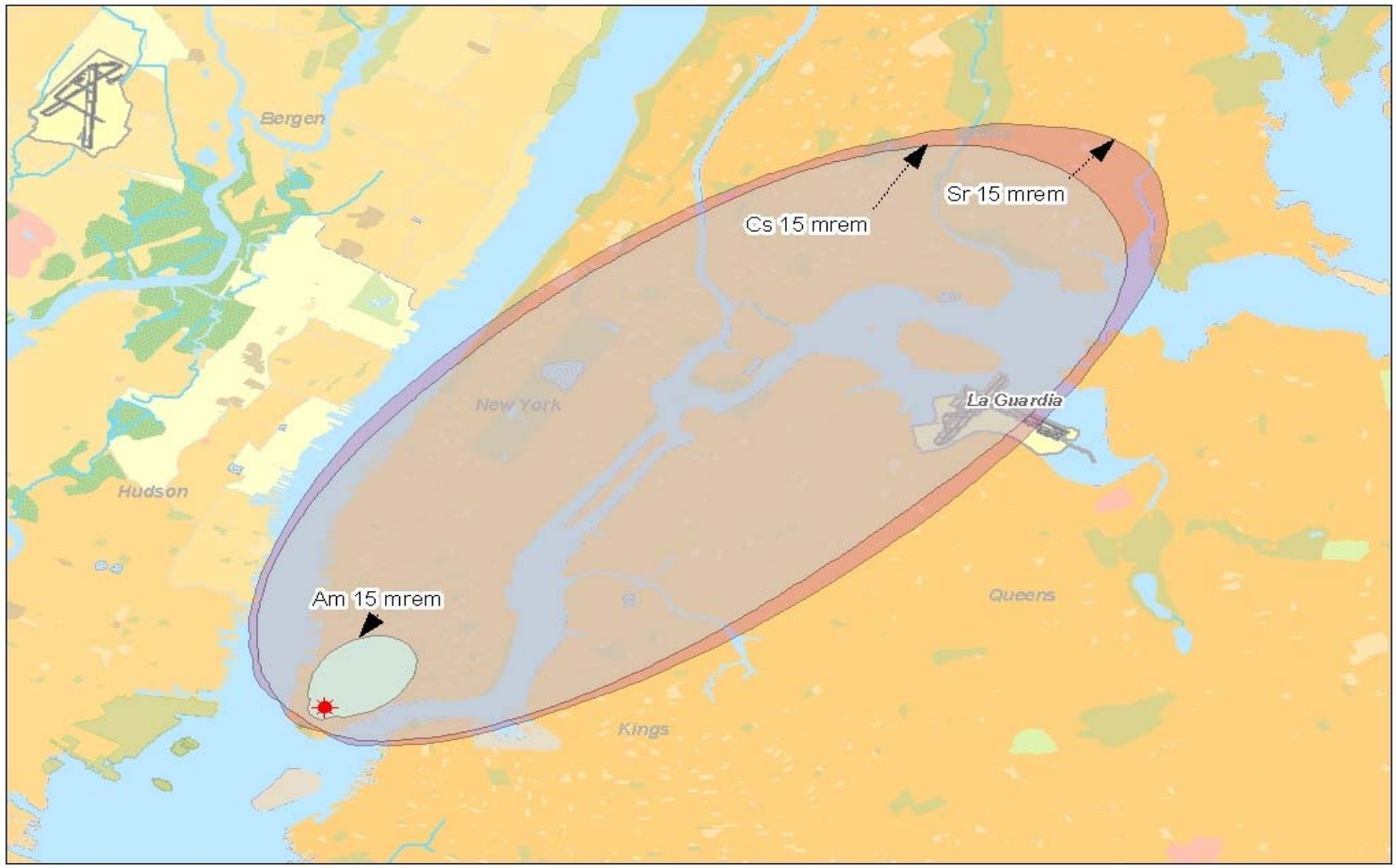
- **Goals**
  - Estimate amount of time it takes to clear debris
    - Post hurricane, earthquake, etc.
  - Predict the effects of debris on electric power restoration
  - Serve as a template for other restoration simulators
- **Algorithm**

Inputs

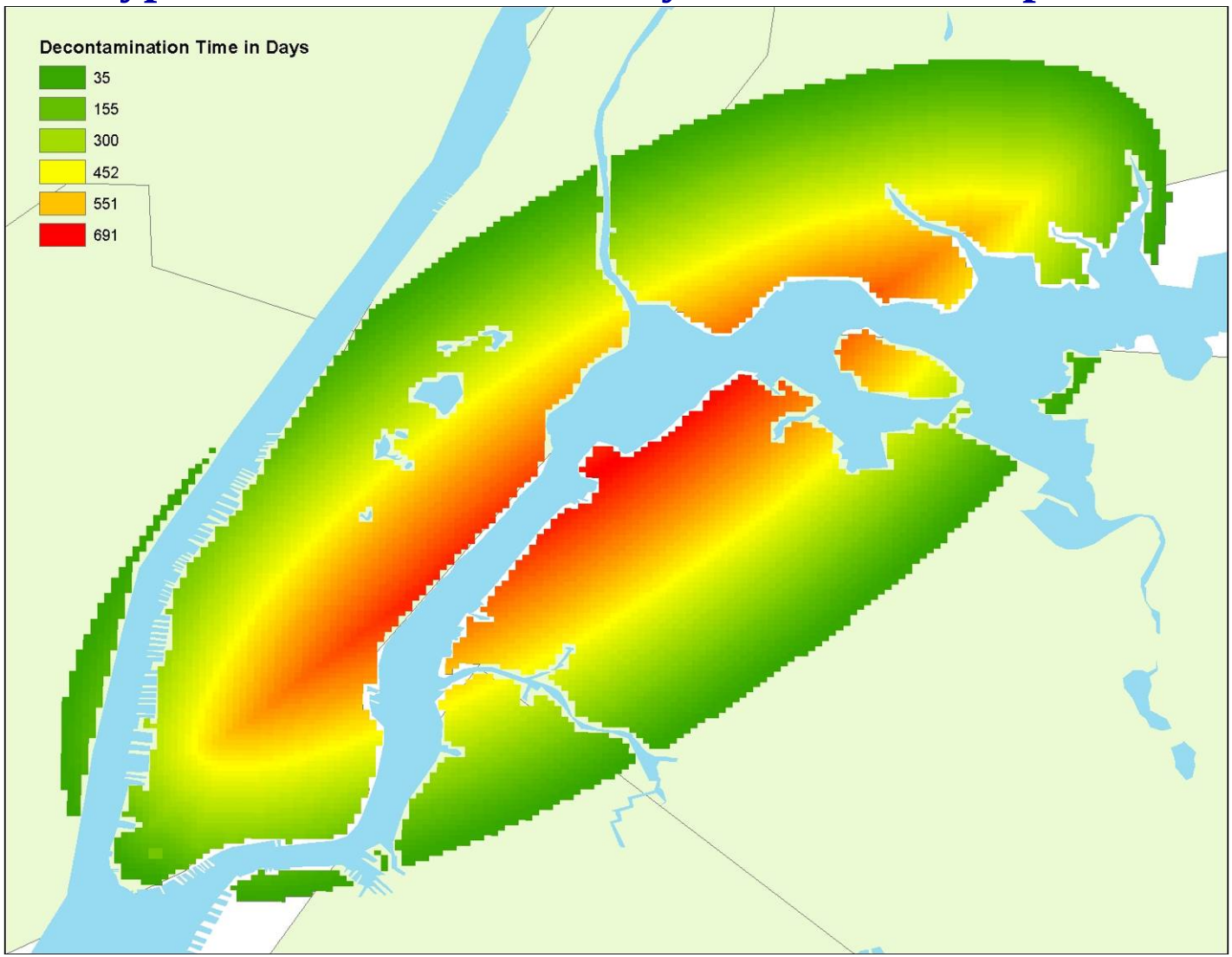
- Amount of Debris
  - Hurricanes
    - County estimates provided by Army Corp of Engineers
    - Army Corp of Engineers formula for hurricane debris calculations (partially complete)
- Debris Regions
  - Electric Power service areas
- Road networks
  - Actual road maps
  - Population density based estimate

A Hypothetical New York Impact Zone

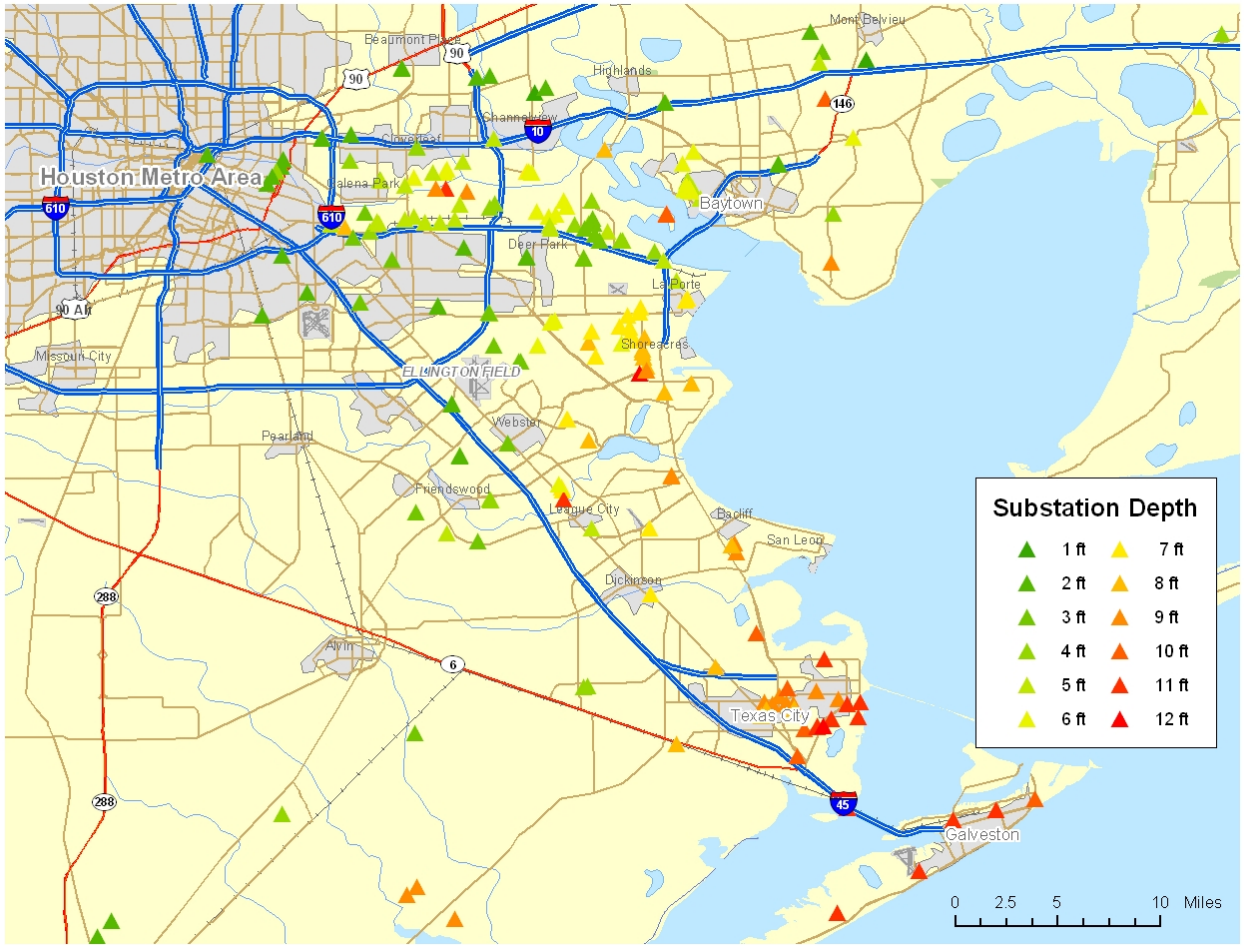
Synthetic Impact



A Hypothetical New York City Restoration Map



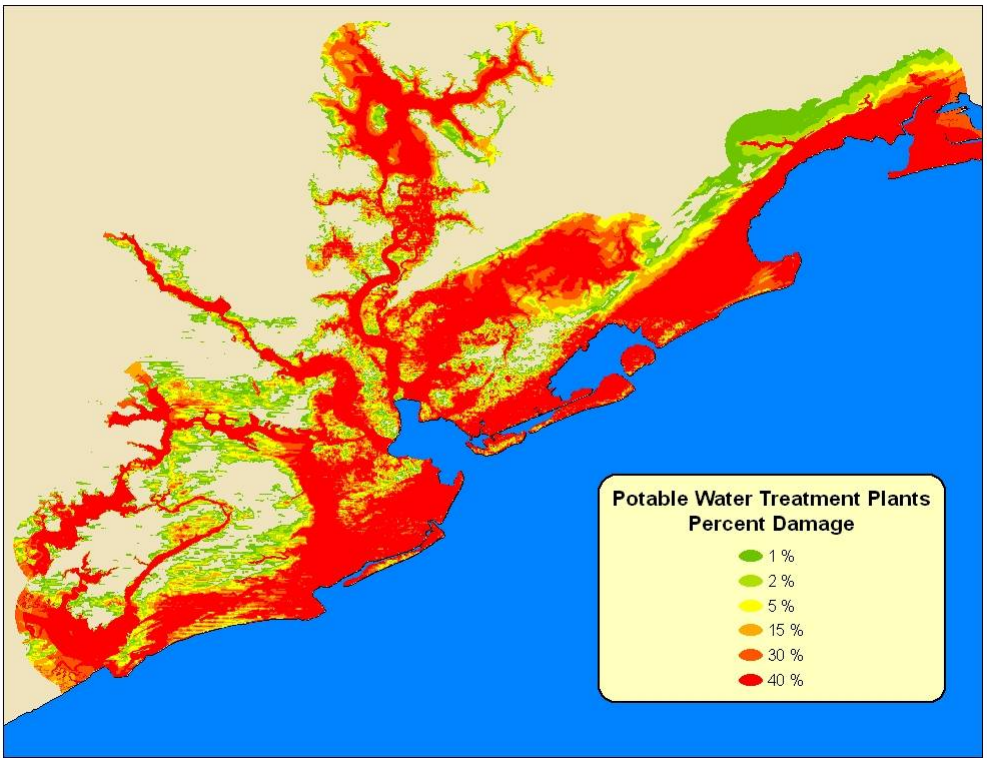
Typical Substation Submersion Estimate



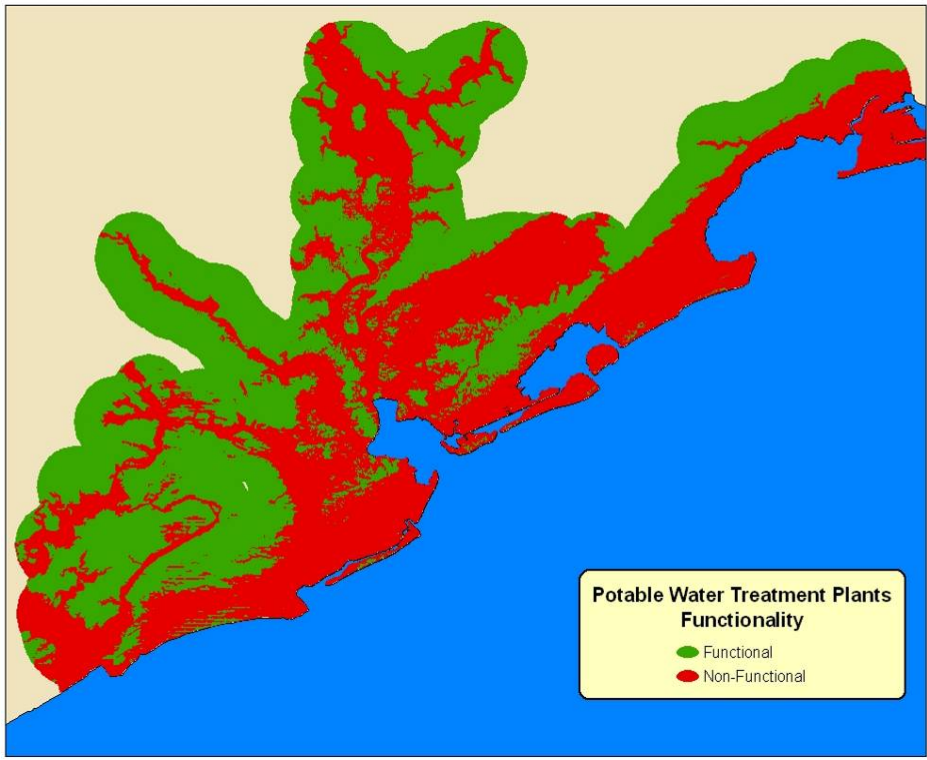
Damage Assessment Tool

Example

- **Hurricane Ernesto, South Carolina**



Percent Damage



Facility Functionality

Summary

- **The time is right to discuss a series of model relationships that we can now weave into a roadmap of inputs/outputs for:**
  - extreme weather modeling,
  - the infrastructure impact and cascading modeling
  - the debris, waterways and flooding modeling
  - the transportation and response models

LA-UR-05-9387


Discussion